Doping-spike LWIR PtSi Schottky IR Detector Fabricated by Molecular Beam Epitaxy*

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The PtSi sensor is among the most promising infrared sensors for large focal plane array applications due to its advantages of uniformity, reliability, and low cost. State-of-the-art PtSi focal plane arrays, with array sizes of 640 x 480 and 1024 x 1024, have been previously demonstrated. The PtSi spectral response follows the Fowler dependence, given by $QE = 1.24\ C_1 \lambda\ (1/\lambda - 1/\lambda_c)^2$, where QE *is* the quantum efficiency, C_1 the emission coefficient, and& the cutoff wavelength. The cutoff wavelength& is determined by the PtSi Schottky barrier $q\phi_B$, given by $\lambda_c = 1.24/q\phi_B$. Current PtSi sensors have cutoff wavelengths ranging from 5.1 to 5.9 μm, limiting their applications in the SWIR (1-3 μm) and the MWIR (3-5 pm) regions.

There is a great interest in extending the PtSi cutoff wavelength, by reducing its effective Schottky barrier height, for the LWIR (8-12 pm) operation and an improved M WIR performance. Previous efforts involves introducing a relatively thick (>50Å) p^+ layer at the PtSi/Si interface (by low energy implantation or molecular beam epitaxy (MBE)). The p^+ layer creates a potential spike near the PtSi/Si interface, allowing photo-excited holes to tunnel into the substrate, resulting in a lower effective potential barrier[2]. However, the additional tunneling process required for the IR detection not only reduces the detector response, but also drastically increases the detector dark current due to the contribution of the undesirable tunneling current.

in this paper, we demonstrated that by thinning the p+ layer to - 10Å, the effective Schottky barrier heights can be reduced without the formation of a potential spike, and consequently, the undesired tunneling process can be eliminated. The doping-spike PtSi detectors were fabricated on double-side polished Si (100) wafers with a resistivity of 30 Ω-cm. The 10-Å-thick p^+-Si layers were grown by MBE at 450 'C using elemental boron as the dopant source with doping concentrations ranging from 5 x1019 to 2×10^{20} cm^{-3}. The PtSi layers were formed *in-situ* by depositing undoped Si and Pt followed by annealing at 400°C. The dark current characteristics of the doping-spike PtSi detectors were found to be thermionic emission limited, given by $Jo = A^{**}\ T^2 exp(-q\phi_B/kT)$. The detector spectral responses were measured with back-side illumination using a 940K blackbody source. 13y varying the doping concentrations of the 1-rim-thick doping spikes from 1×10^{20} cm^{-3} to 2×10^{20} cm^{-3}, the cutoff wavelengths have been extended to 14, 18, and 22 μm, with effective optical potential barriers of 0.09, ().069, and 0.057 eV, determined by Fowler plots, with C_1's comparable to those of conventional PtSi detectors with similar PtSi thicknesses.

In conclusion, we have extended the cutoff wavelength of doping-spike PtSi IR detectors to the LWIR region by incorporating a 10-Å-thick p^+ doping spike at the silicide/silicon interface. The cutoff wavelength increases with increasing doping concentration of the doping spikes. The tailorable cutoff wavelength allows the optimization of the trade-off between the spectral response and the cooling requirements.

1. F. D. Shepherd, Proc. SPIE, Vol. 1735, *Infrared Detectors: State of the Art,* 1992 (to be published).
2. S. M. Sze, *Physics of Semiconductor Devices (Wiley, New* York, 1981), Chap. 5.

$q f$ (eV)

image potential energy

0.2   qEx

tunneling

0.1   effective potential energy

$q f_B = 0.1 e$

E_F

PtSi   0   5   10   15   20   x (rim)

Si

(a)

$q f$ (eV)

image potential energy

%.--

0.2   qEx

0.1   effective potential energy

$q f_B = 0.1 e$

E_F

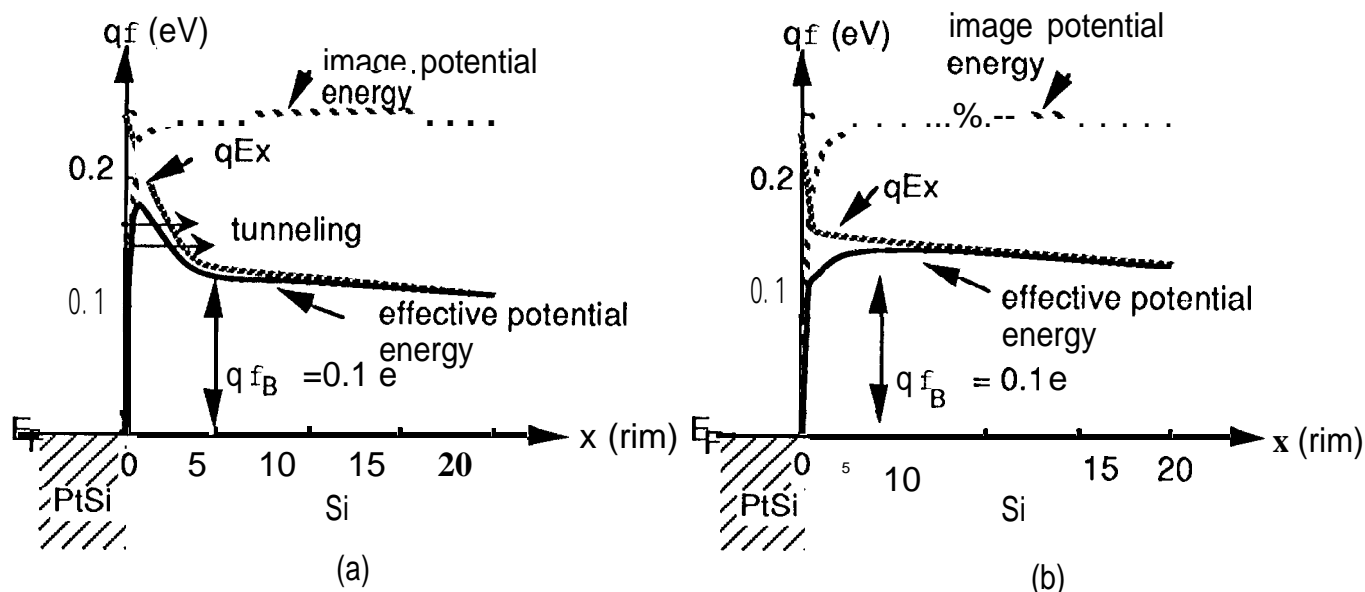PtSi   0   5   10   15   20   x (rim)

Si

(b)

Figure 1.   Calculated energy-band diagrams of two doping-spike PtSi detectors with a 0.1 eV effective barrier height: (a) with a 50-Å-thick spike doped with 6×10^{18} cm^{-3} boron, which results in a potential spike at the PtSi/Si interface, and (b) with a 10-Å-thick spike doped with 1.2×10^{20} cm^{-3} boron. No potential spike is formed for the 10-Å-thick doping-spike PtSi detector,

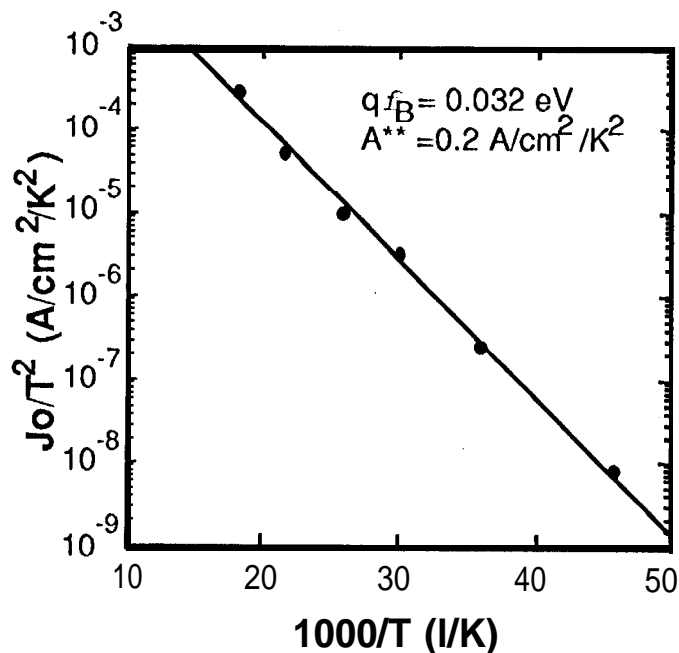$q f_B = 0.032$ eV
$A^{**} = 0.2$ A/cm^2/K^2

J_o/T^2 (A/cm^2/K^2)

10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}

10   20   30   40   50

1000/T (I/K)

$C_1 = 0.143$ eV^{-1}
$q f_B = 0.057$ e

$C_1 = 0.2$ eV^{-1}
$q f_B = 0.090$ e

$C_1 = 0.156$ eV^{-1}
$q f_B = 0.069$

QUANTUM EFFICIENCY

10^1
10^2
10^3
10^4
10^5

2   6   10   14   18   22

WAVELENGTH (pm)

Figure 2. Richardson plot of a typical doping-spike PtSi detector with a 22 μm cutoff wavelength whose photoresponse is shown in Fig. 3.
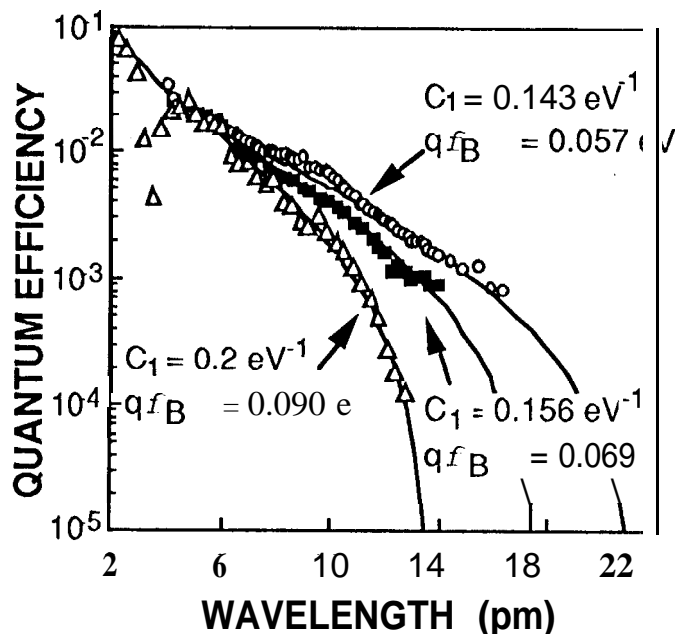
Figure 3. Quantum efficiency as a function of wavelength for the three doping-spike PtSi detectors with 1-rim-thick p$^+$ doping spikes measured at 40K, The cutoff wavelengths can be tailorable from 14 to 22 μm by increasing the p$^+$ spike doping concentration from 1×10^{20} to 2×10^{20} cm^{-3}.